

with Osmi lamp, 1.5 watts per candle-power.—Fery radiation pyrometer: the Cambridge Scientific Instrument Company. By means of a concave mirror the image of a hot body or of the inspection hole in a furnace wall is focused upon a copper-constantan thermo-couple connected to a direct-reading galvanometer on the centigrade scale. The instrument was shown working, being sighted upon a disc of hot iron within an electrical resistance furnace.

Drawings made from combined photographs of the solar corona in 1898, 1900, and 1901: the Astronomer Royal. In 1901 a change in the corona on the west side appears to have taken place in the interval (thirty-seven minutes) between two photographs taken at different stations. The drawings were by Mr. W. H. Wesley.—(1) Photographs, maps, curves, and diagrams, in connection with the more recent researches on the astronomical significance of British stone circles. (2) Contact positives showing some of the results taken with the Solar Physics Observatory spectroheliograph. Also four enlarged pictures showing disc and disc-and-limb photographs, and a photograph of the instrument itself. (3) A series of curves to illustrate the relationship between the flow of the river Thames and pressure and rainfall changes in Great Britain. The close association between British pressure and the barometric see-saw between the Indian and South American areas was also indicated: Sir Norman Lockyer, K.C.B., F.R.S.—A new sundial that tells standard time, designed by Prof. Albert Crehore: Sir W. H. Preece, K.C.B., F.R.S. The gnomon of the common form of dial is abandoned, and the shadow of a small bead fixed on a wire is cast on the interior of a true cylindrical surface, upon which figure-of-eight curves are drawn marking standard noon for each day of the year. The cylindrical surface is inclined so that its axis, upon which the bead is fixed, is parallel to that of the earth. It thus represents the latitude of the place. The shadow of the bead travels across the cylindrical surface parallel to, or on, one of the circles drawn thereon. These circles represent days of the month. Each hour described in the circle is always of the same length, and a scale of minutes engraved on the cylinder enables true mean time to be read off directly to a few seconds.

Photographs illustrating the annual growth of a deer's antlers: Mr. H. Irving. The deer photographed was a wapiti, full grown. The first photograph showed the deer on the second day after the antlers were cast. Succeeding photographs were taken at fortnightly intervals covering four months' growth. The antlers were also shown with the velvet in strips, and finally clean and hard. The antlers of the previous year were shown for comparison.—Mendelian heredity in rabbits: Mr. C. C. Hurst. A pure-bred "Belgian hare," mated with a pure-bred white Angora, gave all wild-grey rabbits. These, bred together, gave the ten types exhibited, in which appear all the possible combinations of four pairs of coat characters, viz. short and angora, coloured and white, grey and black, self-coloured and Dutch-marked. The breeding behaviour of these types demonstrates clearly the Mendelian principles of dominance, segregation, and gametic purity. Dominant characters are short, coloured, and grey coat. Recessive characters are Angora, white and black coat. The black and Dutch-marked characters were introduced by the white Angora.—(1) Individual, local, and orthogenetic variation in Mexican lizards of the genus *Cnemidophorus*; (2) three specimens of *Chirotes canaliculatus* from Rio Balsas, South Mexico: Dr. H. Gadow, F.R.S. The former exhibit included:—*Cnemidophorus dappi*, showing orthogenetic variation in the number of white dorsal stripes from 7 to 11. Local variation from completely white to black underparts; from lateral white spots to double red bands. *C. striatus* and *C. guttatus*. Leading from a sharply striped pattern to the dull-coloured and completely spotted form which is characteristic of the eastern forest region. *C. gularis*, *C. mexicanus*, *C. bocourti*, and other closely allied forms, varying in size, colour, pattern, and scales.—(1) Demonstration illustrating the life-history of wood-boring wasps (Crabronidae); (2) photographs from life of transformations of the brimstone butterfly (*Gonepteryx rhamni*): Mr. Fred Enock. The Crabronidae, or wood-boring wasps, excavate (with their mandibles) deep burrows in decaying tree trunks, palings, &c., their work being carried on day and night

until a sufficient depth has been reached. The female wasp then flies off in search of prey to stock her cells with food for the larvæ. A number of species inhabit Great Britain. Each selects its prey from certain insects, and invariably keeps to the species so selected. The intelligence exhibited by the wasp when "collecting" is marvellous, a momentary glance as the insects dart past being sufficient to identify the right one.—The membranous labyrinth of man and some animals: Dr. Albert A. Gray. The exhibit represented the membranous labyrinths of man, illustrating normal and pathological conditions; the membranous labyrinth of the seal showing otoliths; the membranous labyrinths of the mouse, the rat, the rabbit, the sheep, the cat, the lemur, the duck, the hen. The brain of the haddock, with the otoliths in their natural position.

(1) Restoration of a British Jurassic theropodous Dinosaur of the genus *Streptospondylus* from the Oxford Clay, Oxford; (2) British armoured Dinosaur: Dr. Francis Baron Nopcsa. The bipedal dinosaurian reptile shown in the first exhibit is the most complete representative of the genus discovered in this country. The type exists in the Paris Museum, but is very imperfect. The specimen from which Baron Nopcsa's restoration is prepared is in the private museum of Mr. J. Parker, of Oxford, and is about to be described by the exhibitor. The restoration was executed under the direction of Dr. Francis Baron Nopcsa by Miss Alice B. Woodward. Diagram reconstruction of skeleton and bony dermal armour of *Polacanthus Foxi* Hulke, from the Wealden of the Isle of Wight. Reconstructed by Dr. Francis Baron Nopcsa, under the direction of Dr. Arthur Smith Woodward, F.R.S., and set up in the geological department of the British Museum.

Ethnological specimens from southern Mexico: Mrs. Gadon. The specimens comprised embroidered leather dancing dress; decorated cotton huipiles, from eastern Oaxaca and South Guerrero; white cotton shifts, embroidered with beads, South Guerrero; dancing masks, from Coacoyulchan, South Guerrero; clay and stone idols and sacred vessels; clay whistles, kitchen utensils, ancient and modern; copper, flint, and stone implements; and duck-shaped water vessels.

Photographs of the White Nile and its tributaries, taken by the Survey Department of Egypt, 1903: Captain H. G. Lyons. (1) Bahr el Jebel. The stations of Gondokoro, Lado, Mongalla, and Kiro; in this part the valley floor is about 2-4 feet above low-water level; at Ghoba Shambe and Hellet Nuer it is only 1-2 feet above it, and in this reach the greatest development of the marshes occurs, as well as the blocks of vegetation (Sudd). (2) Bahr el Ghazal and Bahr el Zaraf, showing their flat flood plains. (3) Sobat River in flood near its junction with the White Nile. (4) The White Nile. (5) Shilluk Negroes of the White Nile and Sobat.—Photographic views illustrative of the scenery of Tibet: the Royal Geographical Society.

SUBMARINE NAVIGATION.¹

SUBMARINE navigation has engaged the attention of inventors and attracted general interest for a very long period. Its practical application to purposes of war was made about 130 years ago. Under the conditions which prevailed a century ago in regard to materials of construction, propelling apparatus, and explosives, the construction of submarines necessarily proceeded on a limited scale, and the type practically died out of use, almost at its birth. Enough had been done, however, to demonstrate its practicability and to make it a favourite field of investigation for inventors, some of whom contemplated wide extensions of submarine navigation. Every naval war gave fresh incentive to these proposals, and led to the construction of experimental vessels. This was the case during the Crimean War, when the Admiralty had a submarine vessel secretly built and tried by a special committee, on which, amongst others, Mr. Scott-Russell and Sir Charles Fox served. Again, during the Civil War in America, the Confederates constructed a submarine vessel, and used it against the blockading squadron off Charles-town. After several abortive attempts, and a considerable

¹ Abstract of a discourse delivered at the Royal Institution on Friday, June 9, by Sir William H. White, K.C.B., F.R.S.

loss of life, they succeeded in destroying the Federal *Housatonic*, but their submarine with all its crew perished in the enterprise.

It is impossible to give even a summarised statement of other efforts made in this direction from 1860 onwards to 1880; but one cannot leave unnoticed the work done in the United States by Mr. Holland, who devoted himself for a quarter of a century to continuous experiment on submarines, and eventually achieved success. The Holland type was first adopted by the United States Navy, and was subsequently accepted by the British Admiralty as the point of departure for our subsequent construction of submarines. In France, also, successive designs for submarines were prepared by competent naval architects, and a few vessels were built and tried. The *Plongeur*, of 1860, was a submarine of large size, considerable cost, and well considered design; but her limited radius of action and comparatively low speed left her for many years without a successor on the French Navy List.

The modern development of submarines for war purposes is chiefly due to French initiative. During the earlier stages of this development progress was extremely slow. The *Gymnote* was ordered in 1886 and the *Gustave Zédé* in 1888, and her trials continued over nearly eight years, large sums of money being spent thereon. In 1896 competitive designs for submarines were invited, but no great activity was displayed in this department of construction until the Fashoda incident two years later. Since that time remarkable developments have been made in France, considerable numbers of submarines have been laid down, rival types have been constructed, and many designers have been engaged in the work. Up to the present time about seventy submarines and submersibles have been ordered; in July, 1904, the total number of completed vessels was twenty-eight, and at the end of 1907 it is estimated that France will possess sixty completed submarines, with a total displacement of nearly 13,600 tons. The first French submarine of modern type, the *Gymnote*, was 56 feet long and of 30 tons displacement. The latest types are nearly 150 feet long and of 420 tons displacement. The cost of a French submarine designed in 1898 was about 26,000. The estimated cost of the latest and largest vessels is about 70,000.

Two years elapsed after the date when the French resolutely undertook the construction of submarines before the British Admiralty ordered five vessels of the Holland type from Messrs. Vickers, Sons and Maxim, who had acquired the concession for the use of the Holland Company's patents. These first vessels in essentials were repetitions of the type which had been tried and officially approved by the authorities of the United States Navy. It was agreed that all improvements made by the Holland Company should be at the service of the British Admiralty through the English *concessionnaires*. Our first five submarines are 63 feet in length, 120 tons in displacement, with gasoline engines of 160 horse-power for surface propulsion, giving a speed of 8 to 9 knots. The electric motors for submerged propulsion are estimated to give a speed of about 7 knots. The contract price for each vessel in the United States was about 34,000*l.*, and that is about the price paid for our earliest vessels. The latest type of which particulars are available is said to be about 150 feet in length, 300 tons in displacement, and with gasoline engines of 850 horse-power for surface propulsion, giving a surface speed of 13 knots and a radius of action of 500 miles. The under-water speed is 9 knots, and the radius of action when submerged about 90 miles.

In French official classification a distinction is made between submarines and submersibles, and this terminology has been the cause of some confusion. Both classes are capable of diving when required, and both can make passages at the surface. In this surface condition a considerable portion of the vessel lies above the water-surface and constitutes what is technically called a "reserve of buoyancy." In the submersible this reserve of buoyancy and the accompanying freeboard are greater than in the submarine type, and in this respect lies the chief difference between the two types. The submersible has higher freeboard and greater reserve of buoyancy, which secure better sea-going qualities and greater habitability. The deck or

platform is situated higher above water, and to it the crew can find access in ordinary weather when making passages, and obtain exercise and fresh air. Recent exhaustive trials in France are reported to have established the great superiority of the submersible type when the service contemplated may involve sea passages of considerable length. The French policy, as recently announced, contemplates the construction of submersibles of about 400 tons displacement for such extended services, and proposes to restrict the use of submarines to coast and harbour defence, for which vessels of about 100 tons displacement are to be employed. All recent British submarines would be ranked as submersibles according to the French classification, and it is satisfactory to know, as the result of French experiments, that our policy of construction proves to have distinct advantages.

In addition to these two types of diving or submarine vessels, the French are once more discussing plans which have been repeatedly put forward and practically applied by M. Goubet, namely, the construction of small portable submarine vessels which could be lifted on board large ships and transported to any desired scene of operations. In the Royal Navy, for many years past, it has been the practice similarly to lift and carry second-class torpedo or vedette boats about 20 tons in weight. Lifting appliances for dealing with these heavy boats have been designed and fitted in all our large cruisers and in battleships, and a few ships have been built as "boat-carriers." The first of these special dépôt ships in the Royal Navy was the *Vulcan*, ordered in 1887-8, the design being in essentials that prepared by the lecturer at Elswick in 1883. The French have also built a special vessel named the *Foudre*, which has been adapted for transporting small submarines to Saigon, and performed the service without difficulty. Whether this development of small portable submarines will take effect or not remains at present an open question, but there will be no mechanical difficulty either in the production of the vessels themselves or in the means for lifting and carrying them.

Progress in mechanical engineering and in metallurgy has been great since Bushnell constructed and used his first submarine in 1776, during the war between the United States and this country. These advances have made it possible to increase the dimensions, speed, and radius of action of submarines; their offensive powers have been enlarged by the use of locomotive torpedoes, and superior optical arrangements have been devised for discovering the position of an enemy while they themselves remain submerged. But it cannot be claimed that any new principle of design has been discovered or applied. From descriptions left on record by Bushnell, and still extant, it is certain that he appreciated, and provided for, the governing conditions of the design in regard to buoyancy, stability, and control of the depth reached by submarines. Indeed, Bushnell showed the way to his successors in nearly all these particulars, and—although alternative methods of fulfilling essential conditions have been introduced and practically tested—in the end Bushnell's plans have in substance been found the best. The laws which govern the flotation of submarines are, of course, identical with those applying to other floating bodies. When they are at rest and in equilibrium they must displace a weight of water equal to their own total weight. At the surface they float at a minimum draught, and possess in this "awash" condition a sufficient freeboard and reserve of buoyancy to fit them for propulsion. When submarines are being prepared for "diving" water is admitted to special tanks, and the additional weight increases immersion, and correspondingly reduces reserve of buoyancy. In some small submarines comparative success has been attained in reaching and maintaining any desired depth below the surface simply by the admission of the amount of water required to secure a perfect balance between the weight of the vessel and all she contains, and the weight of water which would fill the cavity occupied by the submarine when submerged. For all practical purposes and within the depths reached by submarines on service water may be regarded as *incompressible*; the submarine should, therefore, rest in equilibrium at any depth if her total weight is exactly balanced by the weight of

water displaced. If the weight of the vessel exceeds by ever so small an amount the weight of water displaced, that excess constitutes an accelerating force tending to sink the vessel deeper. On the contrary, if the weight of water displaced exceeds by ever so small an amount the total weight of the vessel, a vertical force is produced tending to restore her to the surface. In these circumstances, it is obvious that if the admission or expulsion of water from internal tanks (or the extrusion or withdrawal of cylindrical plungers for the purpose of varying the displacement) were the only means of controlling vertical movement, it would be exceedingly difficult to reach or to maintain any desired depth. This difficulty was anticipated on theoretical grounds, and has been verified on service—in some cases with considerable risks to the experimentalists—the submarines having reached the bottom before the vertical motion could be checked. It has consequently become the rule for all submarines to be left with a small reserve of buoyancy when brought into the diving condition. Submergence is then effected by the action of horizontal rudders controlled by operators within the vessels. Under these conditions, submergence only continues so long as onward motion is maintained, since there is no effective pressure on the rudders when the vessel is at rest. The smallest reserve of buoyancy should always bring a submarine to the surface if her onward motion ceases, and, as a matter of fact, in the diving condition that reserve is extremely small, amounting to only 300 lb. (equivalent to 30 gallons of water) in vessels of 120 tons total weight. This is, obviously, a narrow margin of safety, and necessitates careful and skilled management on the part of those in charge of submarines. A small change in the density of the water, such as occurs in an estuary or in the lower reaches of a great river, would speedily obliterate the reserve of buoyancy and cause the vessel to sink if water was not expelled from the tanks. Moreover, variations in weight of the submarine (due to the consumption of fuel, the discharge of torpedoes or other causes) must sensibly affect the reserve of buoyancy, and arrangements must be made to compensate for these variations by admitting equal weights of water in positions that will maintain the "trim" of the vessel. Additional safeguards against foundering have been provided in some submarines by fitting detachable ballast. The more common plan is to make arrangements for rapidly expelling water from the tanks either by means of pumps or by the use of compressed air. In modern submarines, with locomotive torpedoes, compressed air is, of course, a necessity, and can be readily applied in the manner described if it is desired to increase their buoyancy.

The conditions of stability of submarines when diving are also special. At the surface, owing to their singular form, the longitudinal stability is usually much less than that of ordinary ships. When submerged, their stability is the *same in all directions*, and it is essential that the centre of gravity shall be kept below the centre of buoyancy. This involves no difficulty, because water-ballast tanks can be readily built in the lower portions of the vessels. Small stability in the longitudinal sense, however, necessitates great care in the maintenance of trim, and in the avoidance of serious movements of weights within the vessels. Moreover, when a vessel is diving under the action of her longitudinal rudders, she is extremely sensitive to changes of trim, and great skill is required on the part of operators in charge of working the rudders. As the under-water speed is increased, the pressure on the rudders for a given angle increases as the *square* of the velocity, and sensitiveness to change of trim becomes greater. This fact makes the adoption of higher under-water speed a matter requiring very serious consideration. Some authorities, who have given great attention to the construction of submarines, have been opposed to the adoption of high speeds under water, because of the danger that vessels when diving quickly may reach much greater depths than are desirable. Causes of disturbance which might be of small importance when the under-water speed is moderate may have a greatly exaggerated effect when higher speeds are reached. Cases are on record where modern submarines in the hands of skilled crews have accidentally reached the bottom in great depths of water, and have had no easy task to regain the surface.

For these reasons, it is probable that while speeds at the surface will be increased, under-water speeds will not grow correspondingly. Indeed, the tactics of submarines hardly appear to require high speed under water, seeing that it is an important element in successful attack to make the final dive at a moderate distance from the enemy. It is authoritatively stated that in our submarines complete control of vertical movements has been secured by means of skilled operators, and that a constant but moderate depth below the surface can be maintained. Proposals have been made and successfully applied to small submarines for automatically regulating the depth of submergence by apparatus similar to that used in locomotive torpedoes. For the larger submarines now used such automatic apparatus does not find favour, and better results are obtained with trained men.

The possibility of descending to considerable depths has to be kept in view when deciding on the form and structural arrangements of submarines, which may be subjected accidentally to very great external pressure. It is absolutely necessary to success that, under the highest pressure likely to be endured, there shall be rigidity of form, as local collapse of even a very limited amount might be accompanied by a diminution in displacement that would exceed the reserve of buoyancy. This condition is not difficult of fulfilment, and the approximately circular form usually adopted for the cross-sections of submarines favours their resistance to external pressure.

Under former conditions, there was difficulty in remaining long under water without serious inconvenience from the impurity of the air. Now, by suitable arrangements and chemical appliances, a supply of pure air can be obtained for considerable periods, sufficient, indeed, for any operations likely to be undertaken.

The use of gasoline engines for surface propulsion has many advantages. It favours increase in speed and radius of action, and enables submarines to be more independent and self-supporting. Storage batteries can be re-charged, air compressed and other auxiliary services performed independently of any "mother" ship. At the same time, it is desirable to give to each group of submarines a supporting ship, serving as a base and store dépôt, and this has been arranged in this country as well as in France. With gasoline engines, care must be taken to secure thorough ventilation and to avoid the formation of explosive mixtures of gas and air, otherwise accidents must follow.

Little information is available as regards the success of "periscopes" and other optical instruments which have been devised for the purpose of enabling those in command of submarines to obtain information as to their surroundings when submerged. In this department, secrecy is obviously desirable, and no one can complain of official reticence. From published accounts of experimental working abroad as well as in this country, it would appear that considerable success has been obtained with these optical instruments in comparatively smooth water. It is also asserted that when the lenses are subjected to thorough washing by wave-water, they remain efficient. On the other hand, the moderate height of the lenses above water must expose them to the danger of being wetted by spray even in a very moderate sea, and experience in torpedo-boats and destroyers places it beyond doubt that the resultant conditions must greatly interfere with efficient vision. In heavier seas, the comparatively small height of the lenses above water must often impose more serious limitations in the use of the periscopes and similar instruments. Improvements are certain to be made as the result of experience with these optical appliances, and we may be sure that in their use officers and men of the Royal Navy will be as expert as any of their rivals. But when all that is possible has been done, it must remain true that increase in offensive power and in immunity from attack obtained by submergence will be accompanied by unavoidable limitations as well as by special risks resulting from the sacrifice of buoyancy and the great reduction in longitudinal stability which are unavoidable when diving. These considerations have led many persons to favour the construction of so-called *surface-boats* rather than submarines. They would resemble submersibles in many respects, but the power of diving would be surrendered, although they would be so constructed that by admitting

water by special tanks they could be deeply immersed and show only a small target above the surface when making an attack. There would be no necessity in such surface vessels to use electric motors and storage batteries, since internal combustion engines could be used in all circumstances. Hence it would be possible without increase of size to construct vessels of greater speed and radius of action, and to simplify designs in other important features. It is not possible to predict whether this suggestion to adopt surface-boats rather than submersibles will have a practical result; but it is unquestionable that improvements in or alternatives to internal combustion engines will favour the increase of power in relation to weight, and so will tend to the production of vessels of higher speed.

Submarines and airships have certain points of resemblance, and proposals have been made repeatedly to associate the two types, or to use airships as a means of protection from submarine attacks. One French inventor seriously suggested that a captive balloon attached to a submarine should be the post of observation from which information should be telephoned to the submarine as to the position of an enemy. He evidently had little trust in periscopes, and overlooked the dangers to which the observers in the car of the balloon would be exposed from an enemy's gun-fire. Quite recently a proposal has been made by M. Santos Dumont to use airships as a defence against submarines, his idea being that a dirigible airship of large dimensions and moving at a considerable height above the surface of the sea could discover the whereabouts of a submarine, even at some depth below the surface, and could effect its destruction by dropping high explosive charges upon the helpless vessel. Here again, the inventor, in his eagerness to do mischief, has not appreciated adequately the risks which the airship would run if employed in the manner proposed, as submarines are not likely to be used without supporting vessels. Hitherto, submarines themselves have been armed only with torpedoes, but it has been proposed recently to add guns, and this can be done, if desired, in vessels possessing relatively large freeboard. No doubt if gun armaments are introduced, the tendency will be further to increase dimensions and cost, and the decision will be governed by the consideration of the gain in fighting power as compared with increased cost. As matters stand, submarines are practically helpless at the surface when attacked by small swift vessels, and it is natural that advocates of the type should desire to remedy this condition. Surface boats, if built, will undoubtedly carry guns as well as torpedoes, and in them the gun fittings would be permanent, whereas in submarines certain portions of the armament would have to be removed when vessels were prepared for diving.

Apart from the use of submarine vessels for purposes of war, their adoption as a means of navigation has found favour in many quarters. Jules Verne, in his "Twenty Thousand Leagues Under the Sea," has drawn an attractive picture of what may be possible in this direction, and others have favoured the idea of combining the supposed advantages of obtaining buoyancy from bodies floating at some depth below the surface with an airy promenade carried high above water. Not many years ago an eminent naval architect drew a picture of what might be accomplished by utilising what he described as the "untroubled water below" in association with the freedom and pure air obtainable on a platform carried high above the waves. These suggestions, however, are not in accord with the accepted theory of wave-motion, since they take no note of the great depths to which the disturbance due to wave-motion penetrates the ocean. The problems of stability, incidental to such plans, are also of a character not easily dealt with, and consequently there is but a remote prospect of the use of these singular combinations of submarine and aerial superstructures. There is little likelihood of the displacement of ocean steamships at an early date by either navigable airships or submarines, and the dreams of Jules Verne or Santos Dumont will not be realised until much further advance has been made in the design and construction of the vessels they contemplate.

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THE INSTITUTION OF MECHANICAL ENGINEERS.

THE summer meeting of the Institution of Mechanical Engineers was held last week in Belgium. The opening proceedings took place in the city of Liège, the president, Mr. E. P. Martin, occupying the chair at the preliminary sitting. Six papers were down for reading and discussion, the mornings of June 20 and June 21 being devoted to their consideration. The following is a list of the papers:—Superheaters applied to locomotives on the Belgian State railways, by M. J. B. Flamme; the growth of large gas-engines on the Continent, by M. Rodolphe Mathot; ferro-concrete, and some of its most characteristic applications in Belgium, by M. Ed. Noaillon; electric winding machines, by M. Paul Habets; strength of columns, by Prof. W. E. Lilly; an investigation to determine the effects of steam-jacketing upon the efficiency of a horizontal compound steam engine, by Mr. A. L. Mellanby.

The first paper taken was the contribution by M. Flamme on superheating for locomotives. The author first dealt with the Schmidt superheater for simple expansion locomotives as applied on the Belgian State railways. Arrangements were made for superheating the steam, in order further to increase the power of the engines. As a result of experiments made, extending over some months, it was recognised that the utilisation of steam slightly superheated did not offer any appreciable economy of fuel or increase of power. On the other hand, with the Schmidt apparatus, when the steam was superheated from 570° F. to 662° F., favourable results were obtained. Two engines were tried, one using superheated steam and the other saturated steam. The saving in favour of the superheated steam locomotive amounted to 12.5 per cent. for fuel and 16.5 per cent. for water. Moreover, the speed reached showed an average increase of 9.5 per cent., all conditions being exactly the same. In regard to maintenance, the superheated steam locomotive type did not require special attention during its one and a half years' service. These favourable results led to the Belgian State railways venturing on the application of superheat to locomotives on a larger scale. With this in view, twenty-five locomotives, comprising five different types, all provided with the Schmidt superheater, were, at the time of the reading of the paper, actually in course of construction, or were about to be put to work. The Belgian State railway authorities had decided to persevere in their experiments in combining superheating of steam with compounding of the engine. The results obtained will be of very great interest. It was desirable to find whether it was more economical to divide the superheater into two parts in such a manner as to raise the temperature at the entrance to both high-pressure and low-pressure cylinders. The Cockerill Co., of Seraing, had completed a superheater which would enable this question to be settled.

The discussion on this paper was opened by Mr. Robinson, of Messrs. Sharp, Stewart, and Co., who stated that the Schmidt superheater had been tried on the Canadian Pacific Railway, and had been found to answer, whilst on the Cape railways the results had not been so satisfactory. He attributed the latter effect to the fact that the superheating tubes were placed at the lower part of the barrel of the boiler, instead of at the upper part as they should have been. Mr. Mark H. Robinson and the president also spoke.

The next paper taken was that of Mr. Paul Habets on electric winding machines. This was a long and somewhat abstruse paper, illustrated by many diagrams, and containing a large number of formulæ. It was read in brief abstract by the secretary of the institution. The author gave a dynamic investigation of haulage, dealing with the questions of resistance, statical moments, inertia of suspended loads, inertia of rope-roll, the head gear and winding gears of motors, and other elements of design. Formulæ were given for moments of the accelerating forces and power and expenditure of energy. Details of construction of motors were discussed, and some special devices explained. As a practical conclusion, the author stated that it might be safely concluded from trials of which particulars were given that the electric haulage machine,